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The effect of zinc fertilization on yield and quality of commercial processing tomato (*Solanum lycopersicum* L.) cultivars*

Çinko gübrelemesinin sanayi tipi domates (*Solanum lycopersicum* L.) çeşitlerinde verim ve kalite üzerine etkisi

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ABSTRACT

Objective: In this study, conducted in two production seasons, the effects of zinc fertilization on yield and fruit quality of processing tomato varieties (H-1015, Lalin and Kendras) were investigated.

Material and Method: Material consisted of 'H-1015', 'Lalin', and Kendras' processing tomato varieties. The study consisted of 3 different treatments; zinc applied plots, zinc-free plots and control.

Results: The results showed that zinc application to H-1015 and Lalin cultivars gave the highest yield values compared to zinc-free and control treatments in both production seasons. While the differences between the pulp colour values L* and a/b were found to be insignificant in both years, the differences between the values of a* and b* were found to be significant in both years. Similarly, zinc fertilization had no positive effects on the TA and lycopene contents of the varieties. The differences between the fruit pH values of the varieties were found to be significant. While the differences among the Brix values were found to be significant only in 2018, the variety H-1015 showed the highest Brix values in both testing years.

Conclusion: Zinc fertilization is proposed to obtain a high yield in processing tomatoes.

Keywords: Fruit quality, lycopene, processing tomato, yield, zinc sulfate

ÖZ

Amaç: İki üretim sezonunda gerçekleştirilen bu çalışmada, çinko gübrelemesinin sanayi domatesi çeşitlerinde (H-1015, Lalin ve Kendras) verim ve meyve kalitesi üzerine etkileri araştırılmıştır.

Materyal ve Yöntem: Materyal 'H-1015', 'Lalin' ve Kendras' sanayi domates çeşitlerinden oluşmuştur. Çalışma; çinko uygulanan, çinko uygulanmayan ve kontrol olmak üzere 3 farklı parselden oluşturulmuştur

Araştırma Bulguları: Sonuçlar, H-1015 ve Lalin çeşitlerine çinko uygulamasının her iki üretim sezonunda da çinkosuz ve kontrol uygulamalarına göre en yüksek verim değerlerini göstermiştir. Pulp rengi L* ve a/b değerleri arasındaki farklılıklar her iki yılda da önemsiz çıkarken, a* ve b* değerleri arasındaki farklılıklar ise her iki yılda da önemli bulunmuştur. Benzer şekilde çinko gübrelemesi çeşitlerin TA ve likopen içeriği üzerine önemli bir etkisi olmamıştır. Çeşitlerin meyve pH değerleri arasındaki farklılıklar ise önemli bulunmuştur. Briks değerleri arasındaki farklılıklar, sadece 2018 yılında önemli çıkmakla birlikte, H-1015 çeşidi her iki deneme yılında da en yüksek briks değerlerini göstermiştir

Sonuç: Sanayi domatesinde yüksek verim elde etmek için çinko gübrelemesi önerilmektedir.

Anahtar sözcükler: Meyve kalitesi, likopen, sanayi domatesi, verim, çinko sülfat

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a vegetable that belongs to the family of *Solanaceae*, and is widely grown around the world. With a tomato production of 12 million tones, Türkiye ranks first among European countries and fourth in the whole world (FAOSTAT, 2020).

Currently, the tomato is almost at the top of the list of consumed vegetables. Besides being eaten fresh, it is also consumed in processed form in various products such as tomato paste, sauce, tomato juice, and dried tomatoes. For this reason, the tomato varieties produced today are grown for fresh consumption or industry.

The universal purpose of tomato cultivation is to obtain maximum yield and quality fruit from a unit area (Foolad, 2007). Besides, reporting the fact that about half of the increase in the yield is ensured by the variety cultivated through a breeding program (Grandillo et al., 1999), plant cultivation is also very important (Dumas et al., 2003).

Processing tomato varieties are believed to have specific morphological and phenological characteristics. It is preferred that the varieties grown will have an intense inflorescence so that fruit set is good, the fruits are firm, and can harvested immediately; and the fruits are resistant to cracking and can be easily separated from their stems. They should also have low pH, high Brix, and good viscosity (Foolad, 2007).

In the cultivation of processing tomatoes, the use of innovative cultivation strategies ensures a high yield and high quality of the vegetables. However, very high losses occur in the tomato harvest due to reasons such as incorrect harvest management and improper transport conditions. The main objective of breeding programmes and cultivation today is to improve the fruit quality of the cultivated varieties. Fruit size, shape, firmness, color, brix, nutritional content and taste are the most important characteristics (Fridman et al., 2000; Ronga et al., 2019).

High yield and quality of fruit in the cultivation of processing tomato are also depend on the fertilization, as well as the selection of a suitable variety (Dumas et al., 2003; Bettiol et al., 2004). The use of new varieties has increased the amount of nitrogen, phosphorus, and potassium applied to a unit area (Alloway, 2009). High phosphorus accumulation in the soil negatively affects zinc uptake, causing zinc deficiency in plants. (Mousavi, 2011). This condition, which is being called as hidden hunger, is primarily causing significant losses in yield and quality (Alloway, 2009). Zinc is vital role for higher yield and fruit quality of tomato (Ahmed et al., 2021). Previous studies have shown that zinc improves tomato yield and fruit quality (Nawaz et al., 2012; Saravaiya et al., 2014; Harris & Mathuma,2015; Ullah et al., 2015; Singh et al., 2017; Haleema et al., 2018).

Zinc (Zn) ensures the realisation of significant physiological processes in plants, even in very low concentrations. Zn plays a key role in photosynthesis and carbohydrate metabolism, activation of enzymes, gene transcription, growth regulation, seed germination, and especially protein synthesis (Marschner, 2012). Therefore, zinc is one of the important microelements that should be present in crops such as the tomato, as it influences yield and quality.

One of the countries where zinc deficiency is most common in terms of agricultural lands is Türkiye (Alloway, 2009). Studies on zinc tend to focus on grains. Türkiye is one of the most important producers of processing tomato in the world (Anonymous, 2020a). In this sense, the absence of such a study is considered an important deficiency. This study, the effects of zinc fertilization on the yield and fruit quality of three processing tomato varieties (Kendras F1, Lalin F1, and H-1015 F1) widely grown in Türkiye were investigated.

MATERIALS and METHODS

Plant material

In the study, H-1015, Kendras, and Lalin processing tomato varieties were used. All three varieties are extensively grown in the Torbalı district of İzmir, Türkiye. The fruit quality characteristics of the varieties and their resistance to biotic stress conditions differ from each other (Table 1).

Table 1. Fruit quality characteristics of the varieties and their tolerances to biotic stress conditions

Çizelge 1. *Çeşitlerin meyve kalite özellikleri ve biyotik stres koşullarına dayanıklılıkları*

Variety	Average fruit weight (g)	Paste	Peel	Dice	Ve	Fol			N	TSWV	Pst	Pi
						0	1	2				
H-1015	80	x	x	x	x		x	x	x			
Kendras	75–80	x		x	x	x	x		x			x
Lalin	65–70	x		x	x	x	x		x	x	x	

Ve = *Verticillium* spp., Fol = *Fusarium oxysporum* f.sp. *lycopersici* (0, 1 and 2), N = Root-knot nematode (*Meloidogyne incognita, arenaria, javanica*), TSWV = *Tomato Spotted Wilt Virus*, Pst = *Pseudomonas syringae* pv*. tomato*, Pi = *Phytophthora infestans*

H-1015 has an approximate average fruit weight of 80 g and is resistant to *Verticillium* spp. 1, *Fusarium* spp. 1 and 2, root-knot nematode, and bacterial spot disease; it has a brix value of 5.2, and is suitable for use in peeled, diced and paste form (Anonymous, 2020b). Kendras has an approximate average fruit weight of 75–80 g and shows high resistance to the diseases *Verticillium albo-atrum*, *Verticillium dahliae*, *Fusarium* spp. 0 and 1 and normal resistance to root-knot nematode, and late blight. It is suitable for use in the form of paste, cubes, and dried products (Anonymous, 2020c). Lalin has an approximate average fruit weight of 65–70 g and it has high resistance to TSWV, bacterial spot, *Fusarium* spp. 0 and 1, *Verticillium albo-atrum*, and *Verticillium dahliae*, and normal resistance to root-knot nematodes (Figure 1) (Anonymous, 2020d).

The seedlings of the varieties used in the experiment were obtained from TAT Gıda A.Ş. Torbalı Enterprise (Torbalı, İzmir, Türkiye).

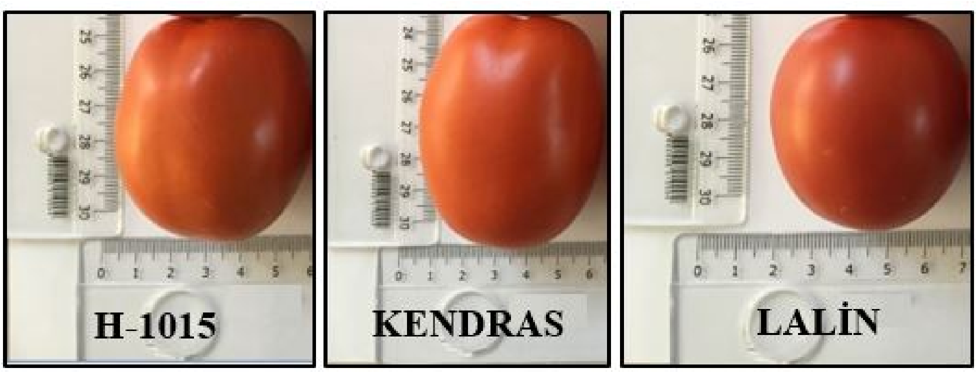

Figure 1. Three fruits representative of the processing tomato varieties used in the experiment: H-1015, Kendras, and Lalin.

Şekil 1. *Denemede kullanılan domates çeşitlerine ait temsili meyve görünümleri: H-1015, Kendras ve Lalin.*

Field conditions and experimental design

The study was conducted in 2017 (38°06'18.0 "N 27°28'21.8 "E) and 2018 (38°06'29.1 "N 27°29'04.9 "E) under field conditions at Gülcüoğlu Farm in Torbalı district of İzmir province. The area where the trial was carried out had a typical Mediterranean climate and in both years of the trial, the minimum and maximum air temperatures from seedling stage to harvest were measured between 6.2 and

41.3 degrees centigrade. The average relative humidity ranged from 51.6% to 63.4% in both years, from seedling stage to harvest (Table 2).

Table 2. Climatic data of the of experimental area

Çizelge 2. *Çalışma alanına ait iklim verileri*

Temperature	2017				2018			
	Months				Months			
	April	May	June	July	April	May	June	July
T max (°C)	30.0	32.8	39.8	41.3	26.1	30.5	33.0	35.7
Average T (°C)	16.4	21.6	26.2	29.4	19.3	23.9	26.8	29.7
T min (°C)	6.2	13.7	17.6	20.3	12.4	18	20.7	23.3
Average RH (%)	54	53.7	51.6	43.8	63.4	59.3	55.6	53.4

T = temperature, max = maximum, min = minimum, RH= relative humidity

Prior to establishment of the experiment, soil samples were obtained from 0–30 cm depth in the autumn season, in both years, and their analysis is given at Table 3.

Table 3. Physical and chemical soil characteristics of the experimental area

Çizelge 3. *Deneme alanı toprağının fiziksel ve kimyasal özellikleri*

Soil characteristics	2017	2018	Methods	Reference
	Result	Result		
pH	6.89	7.34	1: 2.5 soil-water suspension	Horneck et al. (1989)
Salt (%)	0.005	0.009	1: 2.5 soil-water suspension	Horneck et al. (1989)
$CaCO_3$ (%)	0.4	2	Calcimetric	Martin and Reeve (1955)
Organic matter content (%)	0.77	1.04	Walkley - Black	Walkley and Black (1934)
Total N (%)	0.04	0.05	Kjeldahl	Kacar (2009)
Sand (%)	40	20	Hydrometer	Bouyoucos (1962)
Clay (%)	20	20	Hydrometer	Bouyoucos (1962)
Silt (%)	40	60	Hydrometer	Bouyoucos (1962)
Soil texture class	Loamy	Silty loam	Soil Textural triangle (USDA)	Soil Survey Division Staff. (1993)
Available P (ppm)	2.98	9.79	0.5 M $NaHCO_3$ extraction	Olsen (1954)
Available K (ppm)	169	179	1 N NH_4OAc (pH 7.0)	Chapman (1965)
Available Ca (ppm)	442	1363	1 N NH_4OAc (pH 7.0)	Chapman (1965)
Available Mg (ppm)	89	240	1 N NH_4OAc (pH 7.0)	Chapman (1965)
Fe (ppm)	38	15.38	DTPA-TEA (pH 7.3)	Lindsay and Norvell, (1978)
Cu (ppm)	1.47	2.12	DTPA-TEA (pH 7.3)	Lindsay and Norvell, (1978)
Zn (ppm)	0.85	0.83	DTPA-TEA (pH 7.3)	Lindsay and Norvell, (1978)
Mn (ppm)	4.28	3.03	DTPA-TEA (pH 7.3)	Lindsay and Norvell, (1978)

The soil pH of the experimental area is neutral, and there was no salinity problem in both production seasons. Organic matter is low in both years. Total nitrogen (N) was found to be poor, and available potassium (K) was found to be at medium level. Although the available phosphorus (P) was very low in the first year, it was determined as high in the second year. Zinc (Zn) was determined at a critical level in both years, and the other microelements (iron, copper, and manganese) were determined as sufficient (Table 3).

Based on the results of the soil analysis, fertilization programs were prepared, with consideration given to the target yield (Tables 4 & 5). In this context, semi-fertigation (basic fertilization and fertigation) was applied in fertilization (Table 6).

Table 4. Basic fertilizers applied to the experimental plots

Çizelge 4. *Deney parsellerine uygulanan temel gübreler*

Year	Fertilizer	Rate (kg ha^{-1})	N	P_2O_5	K_2O	CaO	MgO
2017	NPK (15-15-15)	750	112.5	112.5	112.5	-	-
	CAN (26% N)	120	31.2	-	-	-	-
	K_2SO_4	50	-	-	25	-	-
	H_3BO_3	7.5	-	-	-	-	-
Total			143.7	112.5	137.5	-	-
Year	**Fertilizer**	**Rate (kg ha^{-1})**	**N**	**P_2O_5**	**K_2O**	**CaO**	**MgO**
2018	NPK (15-15-15)	750	112.5	112.5	112.5	-	-
	CAN (26% N)	120	31.2	-	-	-	-
	K_2SO_4	50	-	-	25	-	-
	H_3BO_3	7.5	-	-	-	-	-
Total			143.7	112.5	137.5	-	-

Table 5. Fertilizers used in the fertigation.

Çizelge 5. *Fertigasyonda kullanılan gübreler*

Year	Fertilizer	Rate (kg ha^{-1})	N	P_2O_5	K_2O	CaO
2017	MAP	40.00	4.80	24.4	-	-
	MKP	30.00	-	15.6	10.2	-
	33% N	150.00	49.5	-	-	-
	K_2SO_4	120.00	-	-	60.0	-
	Ca $(NO_3)_2$	80.00	12.4	-	-	20.8
	Urea (46% N)	40.00	18.4	-	-	-
	Total		85.1	40.0	70.2	20.8
Year	**Fertilizer**	**Rate (kg ha^{-1})**	**N**	**P_2O_5**	**K_2O**	**CaO**
2018	MAP	40.0	4.80	24.4	-	-
	MKP	30.0	-	15.6	10.2	-
	AN (33% N)	140.0	46.2	-	-	-
	K_2SO_4	120.0	-	-	60.0	-
	$Ca(NO_3)_2$	70.0	10.9	-	-	18.2
	Urea (46% N)	40.0	18.4	-	-	-
	Total		80.3	40.0	70.2	18.2

In this context, 750 kg ha^{-1} NPK (15-15-15) was applied to all plots in the experiment area at the start of the two production seasons, one week before planting the seedlings. In addition, 3.5 kg ha^{-1} of herbicide (pendimethalin) was applied to all plots. Fertilizer and herbicide were mixed into the soil with a rotary tiller. 120 kg ha^{-1} calcium ammonium nitrate (CAN), 50 kg ha^{-1} potassium sulphate (K_2SO_4 with low pH) and 7.5 kg ha^{-1} boron (H_3BO_3 - water-soluble boron 20.8%) were used as basic fertilizers in both years. To the zinc treatment parcels, 20 kg ha^{-1} of zinc sulphate ($ZnSO_4.7H_2O$) was soil applied On the control plot, defined as the grower's condition, the grower had applied 750 kg ha^{-1} NPK over the soil and 2 L tonne^{-1} GA_3 over the leaf in both experimental years.

Table 6. Fertigation programme
Çizelge 6. *Fertigasyon programı*

Fertilizer	Fertigation (kg / ha / month)					
	2017			2018		
	May (kg ha^{-1})	June (kg ha^{-1})	July (kg ha^{-1})	May (kg ha^{-1})	June (kg ha^{-1})	July (kg ha^{-1})
MAP	40	-	-	40	-	-
MKP	-	30	-	-	30	-
AN (% 33)	20	80	50	30	70	40
K_2SO_4	20	50	50	20	50	50
Ca $(NO_3)_2$	10	40	30	20	30	20
Urea	-	40	-	-	40	-

The seedlings were planted in a single row in the first week of April in both trial years. The seedlings of all three varieties were planted at 2.9 plants per m^2. Seedlings were planted using a machine with a spacing of 1.4 m between rows and 0.25 m between intra-rows. The experiment was established in randomized blocks design with three different treatments (zinc, zinc- free and control), 3 replicates and 3 varieties; in total 27 parcels (H-1015, Kendras, and Lalin),. Each parcel had 100 plants in four rows, having a length of 6.25 m. and width of 4.2 m.

The irrigation of the experimental plot was carried out using the drip irrigation method. Irrigation was performed once or twice a week, depending on the evaporation rate (ET_0) and the development of the plants. Disease and weed control were carried out as in the former studies (Vural et al., 2000; Nas et al., 2017). Harvest was made when most of the fruits were fully ripened (> 85%) (on 20 July 2017 and 16 July 2018).

Yield and quality characteristics evaluated in the experiment

Data regarding the results of the experiment were obtained from the middle two rows (50 plants) of the plots. The yield per plant (kg plant^{-1}) was determined by dividing total product yield obtained from the plot by the number of plants present .Total yield per hectare (t ha^{-1}) was also determined. The yield of the paste (t ha^{-1}) with a Brix content of 28% was calculated using the yield values and the Brix values obtained from the results of the applications (Vural et al., 2000).

Fruit skin color was measured at the equatorial area on both sides of 10 fruit using a colorimeter (CR-400; Minolta Co., Tokyo, Japan). The average scores were recorded regarding CIEL L* a* b* values (McGuire, 1992). The color measurement was done using the same approach from the fruit pulp samples obtained by splitting the fruit after determining the color values of the fruit.

Brix (%) was determined using a digital refractometer (Atago PAL-1, Japan), with the filtrate (pulp) obtained from the fruit (which were parted by a fruit press) by filtering through the filter paper.

Titratable acidity (TA) was determined by titrating 5 mL of the juice with 0.1 N NaOH to a pH of 8.1. The results were expressed in grams of malic acid per 100 mL of fruit juice by the Association of Official Agricultural Chemists (AOAC) standards.

The pH was measured in filtered fruit juice using a digital pH meter with a glass electrode (Mettler-Toledo MP220, Switzerland). The EC value was determined in filtered fruit juice using a conductivity meter (WTW-İnoLab Tetracan® 325).

Lycopene was measured spectrophotometrically (Varian Cary 100 Bio UV-Visible Spectrophotometer, Australia) with a color wavelength of 503 nm, present in the extract from the treated tomato sample homogenized with acetone used as a solvent. The results were expressed in mg kg^{-1} and calculated using the following formula (Davis et al., 2003).

Lycopene (mg kg^{-1} fresh weight) = A_{503}*62.43 / W

Where: W = the exact weight (g) of tomato added; A_{503} = the absorbance value at 503 nm

Statistical analysis

Analyses of variance were performed using JMP 8 statistical software (SAS Institute Inc., Cary, NC, USA) for the data obtained from the experiment. Student's t-test was used to compare the mean values from both years.

RESULTS and DISCUSSION

Yield

There were significant differences among the treatments in both years (Table 7). The highest of the yield values (yield per plant and total yield) obtained from different variety-treatment combinations was acquired from the control and zinc-free treatment of Kendras variety in both years. The lowest yield values (yield per plant and total yield) were determined from the zinc-free and control treatments of the H-1015 variety (Table 7). However, zinc treatment showed beneficial effects on H-1015 and Lalin cultivars' yield values in both production seasons. With the H-1015 variety, the zinc treatment ranked first in both the first and the second years, with 133.46 t ha^{-1} (zinc-free= 124.63 t ha^{-1}, control = 132.59 t ha^{-1}) and 173.88 t ha^{-1} (zinc-free = 135.24 t ha^{-1}, control = 133.46 t ha^{-1}) respectively. Similarly, with the Lalin variety, the zinc treatment ranked first in both the first and the second years, with 158.93 t ha^{-1} in the first year (zinc-free = 133.03 t ha^{-1}, control = 128.38 t ha^{-1}) and 191.33 t ha^{-1} in the second year (zinc-free = 145.60 t ha^{-1}, control = 137.01 t ha^{-1}) (Table 7).

Table 7. Effect of applications on yield in 2017 and 2018 seasons

Çizelge 7. *2017 ve 2018 sezonlarında uygulamaların verim değerlerine etkisi*

Variety	Treatments	2017			2018		
		Plant yield (kg plant^{-1})	Total yield (t ha^{-1})	Paste output yield (t ha^{-1})	Plant yield (kg plant^{-1})	Total yield (t ha^{-1})	Paste output yield (t ha^{-1})
H-1015	+ Zn	5.60±0.28^{c*}	133.46±6.62^{bc}	25.13±1.62^{c}	6.21±0.26^{bc}	173.88±7.27^{bc}	39.56±2.34^{a}
	- Zn	5.32±0.11^{c}	124.63±2.64^{bc}	23.72±0.09^{c}	4.83±0.30^{d}	135.24±8.28^{d}	27.67±1.55^{bcd}
	Control	5.57±0.19^{c}	132.59±4.44^{bc}	24.13±0.68^{c}	4.76±0.04^{d}	133.46±1.26^{d}	24.93±0.53^{cd}
Mean		5.50	130.23	24.33	5.27	147.53	30.72
Lalin	+ Zn	6.67±0.06^{b}	158.93±1.36^{b}	29.33±0.97^{bc}	6.83±0.68^{ab}	191.33±11.22^{ab}	31.31±2.93^{b}
	- Zn	5.58±0.20^{c}	133.03±4.71^{bc}	23.50±1.73^{c}	5.20±0.19^{cd}	145.60±19.08^{cd}	24.30±3.32^{d}
	Control	5.39±0.62^{c}	128.38±14.84^{bc}	22.06±2.14^{c}	4.89±0.22^{d}	137.01±5.32^{d}	23.91±0.20^{d}
Mean		5.58	140.11	24.96	5.64	157.98	26.51
Kendras	+ Zn	8.39±0.25^{a}	199.87±6.03^{a}	33.57±1.42^{ab}	6.15±0.22^{bc}	172.38±6.30^{bc}	30.16±2.64^{bc}
	- Zn	8.48±0.05^{a}	201.90±1.09^{a}	35.81±0.57^{ab}	7.36±0.30^{a}	206.26±8.51^{a}	32.35±0.76^{b}
	Control	9.16±0.16^{a}	218.01±3.69^{a}	37.65±1.53^{a}	4.95±0.22^{d}	138.60±6.10^{d}	23.96±1.50^{d}
Mean		8.68	206.59	35.68	6.15	172.41	28.82
p		0.037	0.037	0.037	0.0049	0.0049	0.0212

*: Means in the same column followed by the same letter(s) are not significantly different ($p \leq 0.05$) according to Student's *t*-test.

The higher yields obtained by zinc treatment in the varieties Lalin and H-1015 can be attributed to the fact that the plants benefited from more nutrients. Haleema et al. (2018) reported that maximum tomato fruits per plant were attained from foliar application of Zn. Ullah et al. (2015) also reported that maximum yield (23.40 t ha^{-1}) was obtained from the application of 0.4% Zn foliar spray. A previous study reported that $ZnSO_4$ as soil and foliar application treatment increased tomato yield (Prasad et al., 2021). Similarly, Saravaiya and colleagues (2014) showed that maximum fruit yield were obtained from Zn fertilization. Findings in our study are in good harmony with the earlier studies of zinc sulfate treatments either applied to the soil and or to the foliage (Dube et al., 2003; Gurmani et al., 2012; Bashir & Manan, 2012; Shnain et al., 2014; Ali et al., 2015; Sultana et al., 2016).

The reason for the increase in plant development and yield as a result of the zinc-containing treatment could be due to the fact that zinc stimulates the plant's metabolism, increases auxin synthesis in the plant and ensures better nutrient uptake (Cakmak et al., 1999). Agrawal et al. (2010) reported that the application of zinc maximised the uptake of N, P, K, Cu and Fe in tomato.

These authors also stated that this condition was activated because the plant roots benefited from more nutrients. This is due to the increased photosynthesis and the positive effects of root development resulting from the formation of more green parts in the plant owing to the zinc supplied via the soil (Gurmai et al., 2012).

Fruit quality

Although the differences between the pulp color values of the tomato, L* and a/b, were found to be insignificant in both years, the values of a* and b* were found to be significant in both years (Table 8). In the first year, the highest a* value (30.65) was obtained by the Kendras variety from the zinc treatment, and in the second year, the highest a* value (27.65) was obtained by the H-1015 variety from the control treatment. However, the lowest a* value (21.14) was obtained by the variety Lalin from the zinc-free treatment, and in the second year, the lowest a* value (15.19) was obtained by the variety Kendras from the control treatment. When we examined the b* values of the pulp colour, the highest values (22.03 and 18.63) were obtained in both years by the Kendras variety in the zinc treatment and by the H-1015 variety in the control treatment, respectively.

The lowest values (14.27–6.79) were obtained in both years in the Lalin variety by the zinc treatment (Table 8). In this regard, no stable results were obtained regarding the effect of the interaction between variety and treatment on pulp color. Similar results were also obtained in the previous studies conducted in the Torbalı district (Nas et al., 2017, 2018).

Table 8. Effect of zinc treatments on the color values of tomato pulp

Çizelge 8. *Çinko uygulamalarının domates pulp rengi değerlerine etkisi*

Variety	Treatments	2017				2018			
		L*	a*	b*	a/b	L*	a*	b*	a/b
H-1015	+ Zn	50.86±0.79^{ns}	21.49±0.84^{c*}	14.34±0.96^{c}	1.50±0.06^{ns}	44.64±1.17^{ns}	26.87±1.72^{a}	15.43±1.02^{a}	1.74±0.04^{ns}
	- Zn	51.37±0.68	22.77±0.79^{bc}	16.30±0.79abc	1.39±0.02	41.25±0.42	21.21±0.41^{ab}	13.16±0.11^{ab}	1.61±0.03
	Control	52.32±4.01	24.10±1.08^{abc}	16.46±1.51abc	1.47±0.08	44.35±1.15	27.65±2.52^{a}	18.43±2.95^{a}	1.51±0.09
Mean		51.52	22.79	15.70	1.45	43.41	25.24	15.67	1.62
Lalin	+ Zn	50.91±2.10	21.15±0.41^{c}	14.27±1.04c	1.49±0.11	40.53±0.52	12.42±0.94^{c}	6.79±0.62^{c}	1.83±0.03
	- Zn	52.28±2.09	21.14±2.08^{c}	15.31±1.31bc	1.37±0.02	40.78±1.73	12.81±0.57^{c}	7.05±0.84^{c}	1.85±0.18
	Control	46.78±1.30	29.45±1.99^{ab}	21.07±1.11ab	1.39±0.03	44.11±3.39	22.77±4.64^{a}	13.51±3.81^{ab}	1.81±0.24
Mean		49.99	23.91	16.88	1.42	41.81	16.00	9.12	1.83
Kendras	+ Zn	45.85±2.03	30.65±0.41^{a}	22.03±0.95a	1.39±0.07	42.98±1.41	22.77±2.03^{a}	14.72±1.37^{a}	1.55±0.07
	- Zn	51.76±1.01	27.91±1.04^{abc}	18.62±1.74abc	1.51±0.09	45.93±.040	23.51±3.54^{a}	15.68±2.69^{a}	1.51±0.04
	Control	54.01±1.84	27.15±2.26^{abc}	18.83±1.42abc	1.43±0.02	41.55±0.07	15.19±0.83^{bc}	8.27±0.24^{bc}	1.83±0.05
Mean		50.54	28.57	19.83	1.44	43.49	20.49	12.89	1.63
p		0.0589	0.0065	0.013	0.2714	0.0552	0.006	0.0064	0.1578

*: Means in the same column followed by the same letter(s) are not significantly different ($p \leq 0.05$) according to Student’s *t*-test.

ns: Not significant

The findings in the 2017 year showed that the effect of variety × treatment interaction on pH was significant; on the other hand, the effects on titratable acidity (TA), Brix value and lycopene contents were insignificant. In the second year, the effect of variety × treatment interaction on pH, Brix and lycopene amount was significant, but the effect on TA amount was not significant (Table 9). In this respect, the lowest pH values were measured in the variety Kendras in both of the study years. These values were 4.81 for the zinc-containing treatment in the first year and 4.74 for the zinc-free treatment in 2018 (Table 9).

Previous studies have shown that zinc sulfate fertilizer has a significant impact on the quality of the tomato. Kazemi (2013) reported that the highest fruit lycopene content, titratable acidity, pH, and Brix were observed from the treatment of a combined foliar spray consisting of Zn and Fe. Swetha and colleagues (2018) reported that the maximum Brix, acidity, and ascorbic acid were found by the application of zinc sulfate along with copper boron, and iron. However, Ejaz et al. (2011) discovered that the foliar application of Zn (6%), B (5%), and N (2%), individually, titratable acidity content, and total soluble solids (TSS) presented extraordinary results.

The reason why the Kendras variety has a lower pH value than the other two varieties is that it ripens later than the H-1015 and Lalin varieties due to the pH of the tomato fruit increasing with ripening. Nas et al. (2018) reported that pH at two different harvest dates, namely the first and second harvest of processing tomatoes grown in three different soil types, indicated an increase at the second harvest. Similar to this, Anthon et al. (2011) showed in their research how late harvesting affected the fruit pH and TA in four varieties of processed tomatoes (H2401, N6368, H9557 and AB2). According to their results, the pH increased as the fruit maturation and increased by 0.01 to 0.02 per day when the harvest was postponed. Our results were in agreement with these studies.

Table 9. Effect of treatments on quality characteristics in 2017 and 2018.

Çizelge 9. *2017 ve 2018 sezonlarında uygulamaların kalite özelliklerine etkisi*

Variety	Treatments	2017				2018			
		pH	TA (g /100 ml)	Brix (%)	Lycopene (mg kg^{-1})	pH	TA (g /100 ml)	Brix (%)	Lycopene (mg kg^{-1})
H-1015	+ Zn	5.10±0.01^{a*}	0.35±0.02^{ns}	5.26± 0.13^{ns}	47.00±11.46^{ns}	4.90±0.03^{b}	0.31±0.02 ^{ns}	6.36±0.22^{a}	41.83±4.09^{c}
	- Zn	5.00±0.03^{abc}	0.35±0.01	5.33±0.09	73.24±4.48	4.97±0.01^{ab}	0.32±0.00	5.73±0.03^{b}	47.40±4.34^{c}
	Control	5.02±0.03^{ab}	0.36±0.01	5.10±0.06	60.84±3.22	4.93±0.01^{b}	0.29±0.00	5.23±0.15^{bc}	66.25±0.27^{ab}
Mean		5.04	0.35	5.23	60.36	4.93	0.31	5.77	51.83
Lalin	+ Zn	4.94±0.040^{bcd}	0.40±0.01	5.16±0.15	70.61±12.43	5.02±0.03^{a}	0.37±0.01	4.56±0.18^{d}	47.65±4.08c
	- Zn	4.92±0.01^{bcd}	0.34±0.00	4.93±0.19	42.32±10.02	4.94±0.03^{b}	0.34±0.01	4.66±0.03^{d}	70.30±2.97^{a}
	Control	4.86±0.02^{d}	0.36±0.01	4.83±0.09	48.69±6.58	4.83±0.01^{c}	0.34±0.02	4.90±0.15^{cd}	64.32± 3.58^{ab}
Mean		4.91	0.37	4.97	53.87	4.93	0.35	4.71	60.76
Kendras	+ Zn	4.81±0.01^{d}	0.37±0.01	4.70±0.06	46.23±6.93	4.81±0.01^{c}	0.35±0.02	4.90±0.38^{cd}	70.11±3.13^{a}
	- Zn	4.82±0.01^{d}	0.37±0.01	4.96±0.09	46.47±11.52	4.74±0.03^{d}	0.37±0.02	4.40±0.10^{d}	73.13±3.54^{a}
	Control	4.87±0.03^{cd}	0.35±0.01	4.83±0.13	46.67±4.13	4.68±0.02^{d}	0.36±0.01	4.83±0.09^{cd}	58.65±4.12^{b}
Mean		4.83	0.36	4.83	46.46	4.74	0.36	4.71	67.30
p		0.0398	0.0554	0.2882	0.0899	0.005	0.4563	0.0096	0.0008

*: Means in the same column followed by the same letter(s) are not significantly different (p≤0.05) according to Student's *t*-test.

ns: Not significant

CONCLUSIONS

Findings of this study showed that H-1015 and Lalin varieties yield (plant yield, total yield, and paste output yield) the highest when zinc was applied pointing out that these varieties respond better to Zn fertilization. Therefore, zinc fertilization should be considered when cultivating these varieties, taking into account the soil analysis results.

In both of the study years and for all varieties, different fruit and pulp results (L*, a*, b*, and a/b) were obtained zinc treatment caused a significant difference in both fruit and pulp color. Low pH and high lycopene contents of the fruits were not affected by zinc treatment in all the three varieties. In detail, this means that the zinc treatment does not end up by positive results to achieve low pH and high lycopene in the cultivation of H-1015, Lalin, and Kendras.

According to these results, zinc fertilization could be performed to obtain a high yield when cultivating the varieties H-1015 and Lalin.

Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: YN, İD; sample collection: YN; analysis and interpretation of data: YN, İD; statistical analysis: YN; visualization: YN, İD; writing manuscript: YN, İD.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that there is no need for an ethics committee for this research.

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